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Physical Behaviours and Fundamental Movement skills in British and Iranian children: An Isotemporal Substitution Analysis

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Running Head: FMS in British and Iranian children

Abstract

Although the relationship between fundamental movement skills (FMS) and physical behaviours has been established; differences between countries are scarcely explored. The impact of the whole physical behaviour composition, in relation to FMS, has yet to be investigated in 9-11y children. The aims were, to investigate the associations of substitution of physical behaviours with FMS score, to compare traditional linear regression and compositional data analysis and compare between England and Iran. Measures included accelerometer-derived activity (sleep (SL), sedentary behaviour (SB), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) and FMS, using the TGMD-2, in 119 children (64 boys) from Iran (mean (±SD) age: 9.8±0.3y; BMI of 18.2 ±3.3kg/m^2) and 139 (61 boys) children from England (mean (±SD) age: 9.5±0.6y; BMI of 17.7 ±3.1kg/m^2). Isometric log-ratio multiple linear regression models were used to discern the association between FMS and the mean activity composition, and for new compositions where fixed durations of time were reallocated from one behaviour to another, while the remaining behaviours were unchanged. In physical behaviours as a composition, FMS was significantly associated in both ethnicities. English children responded significantly positively to adding 5 or more minutes LPA at the expense of SB (FMS unit change from 0.05 [0.01,0.09] at 5 min to 0.72 [0.01, 1.34] at 60min). Adding 10 minutes or more of SL, at the expense of SB, was associated with a significant, positive change in FMS in all children. Investigation is needed to understand the composition of SB and its potential influence on FMS development.

Key words

Fundamental movement skills, physical activity, sedentary behaviour, isotemporal substitution, children, composition

Introduction

The prevalence of global obesity epidemic has increased dramatically over the last 40 years. In 1975 5% of children aged 5-19 years were classified as overweight or obese and this has risen to 25% worldwide[1]. It has been well documented that obesity is a multifactorial condition, with one of the main contributors being physical inactivity. Developed countries such as the UK have a much higher prevalence of obesity and physical inactivity compared to developing countries [1].

Physical behaviours, including sleep (SL), sedentary behaviour (SB), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA), are known to be interrelated, and health benefits may be optimized when all components of these behaviours are considered[2]. The link between MVPA and maintenance of a healthy body mass has been well established[3]; in addition, the relationship between fundamental movement skill (FMS) competency and childhood PA has been highlighted across the world, being identified in England[4], Australia[5], Finland[6], Ireland[7], Netherlands[8], America[9], and Indonesia[10], to name a few.

However, despite positive associations being routinely reported between specific behaviours, most often MVPA, and FMS, considering physical behaviours in an isolated manner is a statistically flawed approach, given that such behaviours are necessarily bound to 1440 minutes per day and co-exist as a whole or composition, and thus, the time spent in one behaviour effects, and is affected by, the other behaviours during the remaining time of the day[11]. Indeed, to combat this statistical incongruity, some studies have used a compositional data analysis approach in order to understand the relationship between physical behaviours and health outcomes[12], and recently, compositional data analysis has been utilised to discern the relationship between physical behaviours and FMS in pre-school children[13]. However, an isotemporal substitution model has not been reported between PA intensities and FMS competency score in primary school children (9-11y), so it remains unknown how time reallocated from SB, SL, or LPA to MVPA might affect FMS scores in this population. Additionally, due to developing and developed countries reporting differing PA and obesity rates [1], it should not be assumed that results can be generalised across cultures.

Therefore, the aims of this research were threefold; firstly, to investigate the cross-sectional associations of substitution of PA behaviours with FMS score, secondly, to compare traditional linear regression and compositional data analysis of physical behaviour data, and thirdly, to compare results between a developed (England) and developing country (Iran).

Materials and Methods

Participants

Following institutional ethical approval from the LSI sub-committee at Middlesex University and signed informed parental consent, 119 children (64 boys) from Iran (mean (±SD) age of 9.8±0.3 years and BMI of 18.2 ±3.3kg/m^2) and 139 (61 boys) children from England (mean (±SD) age of 9.5±0.6 years and BMI of 17.7 ±3.1kg/m^2) were recruited. Children's date of birth and sex were provided, and pseudo anonymised by the schools. Participants were recruited from socially deprived areas, as defined by their respective National indices of deprivation (UK and Iran, respectively).

Anthropometric measures

Children's height and mass were measured using a stadiometer (Seca, Germany model: SECA213) and electronic weighing scales (Seca, Germany model: SECA877). From this data, BMI was calculated (kg/m2).

Fundamental movement skill competency

The test of Gross Motor Development 2nd edition (TGMD-2) was employed to assess FMS competency[14]. This test consists of six locomotor skills: run, leap, horizontal jump, slides, gallop and hop and six object-control skills: the throw, catch, kick, dribble, roll and strike. Digital video cameras (Canon, Japan model: Legira HF R48-05) were set to record the children's performance. Before each test, assessors visually demonstrated the correct techniques for every skill, however children were not told which components were being assessed. Then children performed every skill twice and their performance was recorded. Each skill consists of different specific movement criteria. Movement process characteristics were rated as '1' if a participant presents the behaviour and '0' if the behaviour is absent. Each skill was performed twice, therefore, each component had a score out of two. The sum of the component scores gave the raw scores for that skill. The raw scores of the six skills were then summed to provide scores for object control skill and locomotor skill (both subtest scores ranged from 0–48). Then the total score of FMS was provided by adding the scores of the two subtests (ranged from 0–96). The higher the scores the better developed the child's locomotor, object control, and FMS, while low scores indicate weak developed skills.

Physical activity assessment

Physical activity was measured objectively for seven days using The GENEActiv accelerometers which have demonstrated high criterion and concurrent validity[15]. The metabolic equivalent (MET) intensity levels to measure sedentary (<1.5 METs), light (1.5-<5 METs), moderate (3–5.99 METs) and vigorous (≥6 METs) intensity activities were used[15]. Children wore the accelerometers on their wrist for seven days during the waking hours including bathing and aquatic activities.

Participants with four or more valid days (including one weekend day) were included in the analysis[15], whilst non-wear time was defined by at least 60 min of consecutive movement counts of 0, allowing for up to 2 min of movement counts between 0 and 100[16]. Since participants did not utilise sleep diaries, sleep onset and offset were detected using an automatized algorithm, and sustained inactivity periods (based on low variability in the accelerometer z-angle) within these times were assigned to sleep, in accord with the work of Van Hees and colleagues[17.18]. Sixty second epochs were used for analysis[15], and the average minutes per day spent in SL, SB, LPA, and MVPA was calculated.

Data analysis

Compositional data analyses were conducted in R (http://cran.r-project.org; R Core Team, version 3.6.1, 2019) using the compositions (version 1.40-1)[19], robCompositions (version 0.92-7)[20], and lmtest (version 0.9-35)[21] packages. Standard and compositional descriptive statistics were computed for comparison; where, alternate to the standard arithmetic mean, the compositional mean is obtained by, firstly, computing the geometric mean for each individual behavior (time spent in SL, SB, LPA, and MVPA) and subsequently normalizing the data to the same constant as the raw data, i.e. 1. This measure is coherent with the relative and symmetrical scale of the data[22], whilst univariate statistical measures of dispersion, for instance standard deviation, are not coherent with the intrinsic inter-dependent multivariable nature of compositional data. Thus, multivariate dispersion of day composition was described using pairwise log-ratio variation[23]. The variability of the data was summarized in a variation matrix that contains all pair-wise log-ratio variances, where a value close to zero indicates that time spent in two respective behaviors are highly proportional, whilst a value close to 1 indicates the opposite.

We adopted a compositional approach based on an isometric log-ratio (ilr) data transformation, adapted from Hron[24] (see: [13] and [25]) to adequately adjust the models for time spent in the other behaviours. Briefly, the ilr coordinates were created using a sequential binary partition (SBP) process[26], which were obtained by partitioning the composition, where one set is designated to appear in the numerator of the first ilr coordinate, and the other in the denominator, next, one of the previously constructed sets is further partitioned into two sets, again coding the parts to be in the numerator (+1), the denominator (-1), and uninvolved parts (0). The final ilr's were constructed as normalized log ratios of the geometric mean of parts[11].

Covariates (age, BMI, and sex) were additionally included as explanatory variables. The ilr multiple linear regression models were further checked for linearity, normality, homoscedasticity, and outliers to ensure assumptions were not violated. The significance of the physical behaviour composition (i.e., the set of ilr coordinates) was examined with the 'car::Anova()' function, which uses Wald Chi squared to calculate Type II tests, according to the principle of marginality, testing each covariate after all others. The ilr multiple linear regression models were used to identify differences in the outcome variables associated with the reallocation of a fixed duration of time between physical behaviours, whilst the third and fourth remained unchanged. This was done by methodically creating a range of new activity compositions to mimic the reallocation of 5 min between all physical behaviour pairs, using the mean composition of the sample as the baseline, or starting composition. The new compositions were expressed as *ilr* coordinate sets, and each subtracted from the mean composition *ilr* coordinates, to generate *ilr* differences. These *ilr* differences (each representing a 5-minute reallocation between two behaviours) were then used in the linear models to determine estimated differences (95% CI) in all outcomes. This was repeated for pairwise reallocations, in 5-minute increments, from 5-to-60 minutes, respectively. The rationale for starting reallocation at 5-minutes is based on the fact that the revised 2019 PA guidelines for the UK[27] and US[28] have removed the 10-minute minimum bout duration for all age groups, and specifically for children, as there is not sufficient evidence for this. In addition, a descriptive comparison between UK and Iranian cohorts was reported.

Results

Compositional means for SL, SB, LPA, and MVPA, and FMS scores are presented in Table 1. Children in Iran spent a significantly longer time engaged in MVPA (~57mins/day^{-1}, 95% CI [38, 76], d = 0.74, P<0.001) and SB (~60mins/day^{-1}, 95% CI [32, 87], d = 0.54, P<0.001), and significantly less time engaged in LPA (~83mins/day^{-1}, 95% CI [58, 108], d = 0.82, P<0.001), compared to UK children. There was no significant difference in FMS between UK and Iranian children (P=0.49).

Table 1 near here

The variability of the overall data is summarized in the variation matrix (Table 2) containing all pair-wise log-ratio variances. A value close to zero suggests that the time spent in the two respective behaviours are highly proportional. For instance, the variance of log(Sleep/Sedentary) is 0.136, which reflects the (proportional) relationship or co-dependence between the two behaviours. The highest log-ratio variance involves MVPA, suggesting that time spent in MVPA is the least co-dependent on any other behaviour. No significant differences were evident between UK vs Iranian cohorts.

Table 2 near here

Linear regression

Data were examined using linear regression, for each movement behaviour independently. Results highlighted that no single behaviour was significantly associated FMS score, besides MVPA in the Iranian children, only (Table 3).

Table 3

Compositional analysis and isotemporal substitution

When data were considered as a composition, adjusted for age, BMI and sex**;** the 24-hour composition was significantly associated (95% CI) with FMS for the whole (P=0.001; r^2=0.08), the UK only (P=0.01; r^2=0.12), and Iran only samples (P=0.0001; r^2=0.14), respectively. Following comprehensive isotemporal substitution (**appended Table**), English children responded in a significantly (95% CI) positive manner to adding LPA at the expense of SB; with a FMS unit-change of 0.05 [0.01,0.09] at 5 min, increasing to 0.72 [0.01, 1.34] at 60min. Adding 10 minutes or more of SL, at the expense of SB, was associated with a significant, positive change in FMS in both Iranian and UK children (all: 0.3 [0.01,0.6]; English: 0.32 [0.01, 0.63]; Iran: 0.29 [0.01, 0.58].

Discussion

The aims of this research were threefold; firstly, to investigate the cross-sectional associations of substitution of PA behaviours with FMS score, secondly, to compare traditional linear regression and compositional data analysis of physical behaviour data, and thirdly, to compare results between a developed (England) and developing country (Iran). Initially, the data were examined using traditional linear regression and the only variable that was associated with FMS was MVPA in Iranian children. This is inconsistent with previous research that has reported that PA may be a significant predictor of FMS in English children[4]. Although, Bryant et al., (2014)[4] used pedometers as a habitual PA measure and, thus, could not determine intensity, suggesting that perhaps different intensities are more important for FMS in English children.

When the physical behaviours were considered as a composition in the present study, FMS was significantly associated in both ethnicities, highlighting that it is the composition of daily behaviour that is more important than any singular component. Furthermore, when systematic isotemporal substitution was conducted, English children responded in a significantly positive manner to adding LPA at the expense of SB. Westerterp and Plasqui (2004)[29] also supports the theory of the importance of LPA to English children's health. However, the same reallocation in Iranian children was equivocal. When MVPA was added at the expense of sleep, there was not any significant positive or negative results. However, adding 10 minutes or more of SL, at the expense of SB, was associated with a significant, positive change in FMS in both Iranian and UK children. The majority of PA guidelines, globally, encourage children to sit less and move more, with a focus on more MVPA[30]. It is clear from the key results described in this study, that it is as not as simple as removing sedentary time and replacing it with MVPA to elicit positive changes in children's FMS, particularly given that FMS are considered a prerequisite for PA[4].

From the analysis presented in this study, it is apparent that the composition of SB in both English and Iranian children needs to be better understood to identify if certain types of SB are more or less beneficial to FMS competency and PA. Indeed, SB tends to have a negative connotation[31] as it has been associated with obesity/obesity related diseases [32], and is often used interchangeably with screen time[31]. However, there are many types of SB, of which, some are very important to a child's development, such as reading, writing, fine motor tasks and creativity (art and music)[33-36]. Furthermore, it was reported by Stamatakis et al (2013)[37], in children aged 2-12 years, that television viewing, but no other type of screen time, was associated with cardiovascular risk markers, independently of PA. Moreover, the authors posited that relying on a single indicator of screen time or SB is likely to conceal specific associations. Indeed, in the present study, theoretical changes in SB did not necessarily confer negative consequences to FMS, exemplifying the need to better discern types of SB[37].

Obesity and obesity related diseases are highly prevalent in both the UK[38] and Iran[39], although culturally they are very different[40]. In Iran, children spend around 4.5 hours in school compared to English children who spend around 6 hours. This could explain some of the differences seen in the PA behaviours between the two countries. Time spent in school has been reported to be predominantly sedentary due to the more traditional academic pressures[41]. In Iran, there is a large emphasis on academic performance from schooling authorities and parents, which have been linked to declines in PA levels of Iranian children[42-44]. Thus, indicating that children in Iran will be more sedentary in school time may explain why they spend significantly more time in SB, per day, compared to English children. However, we concurrently highlighted that Iranian children spent significantly more time engaged in MVPA compared to English children. This demonstrates the need to understand if Iranian children are more active outside of school because there is more time for leisure activities due to the shorter school day. Although, it has also been reported that in developing countries there is a lack of open spaces and playgrounds in schools and communities, which have been highlighted as barriers for children's physical activity[45]. In England, living in a low socioeconomic status (SES) has been linked to higher levels of obesity and lower levels of PA[41]. However, in Iran, living in a higher SES has been linked to higher rates of obesity and lower PA levels[39], agreeing with other research and traditional cultural values in developing countries. The two samples in this study were from low SES status areas, as defined by national indices of deprivation, thus indicating some cultural differences within this status that could determine how SB is spent and where/how MVPA is achieved.

Conclusion

This study is the first to highlight a cross-cultural comparison of a developed vs. developing country using isotemporal substitution and compositional analysis. From the analysis completed, and the discussion points raised, it is clear that future research must seek to discern the make-up, or type, of SB, and '*where'* children accrue their MVPA; this would yield a greater understanding on what is most influential for the development or improvement of FMS competency with regards to the daily physical behaviour composition.

Perspective

This study provides novel insight into the cross-sectional associations of substitution of physical behaviours with FMS score, and provides the first comparison between a developed (England) and developing country

(Iran). When viewed compositionally, daily behaviours are significantly associated with FMS. However, when this composition is analysed using isotemporal substitution, children from Iran and the UK appear to respond differently. Greater granularity in the characterisation of PA and SB is required to better understand how the daily composition impacts on FMS. Furthermore, this study indicates that caution needs to be taken when interpreting results across cultures and demographics, alongside recommendations for children being feasible within the lifestyle norms for a population to maximise potential benefits. Finally, with regard to practical considerations; researchers and practitioners must consider the feasibility and practicality of advocating large increases in PA. and the likely differences in children who already do vs. do not meet 24h movement guidelines.

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Table 1. Descriptive statistics of time-use, FMS, and participant characteristics

	All	UK	Iran
Sleep (min·day^{-1})	680.8 (47%)	680.6 (48%)	674.9 (47%)
SB (min·day^{-1})	341.7 (24%)	311.9 (21%)	366.2 (25%)
LPA (min·day^{-1})	318.8 (22%)	370.1 (26%)	278.1 (19%)
MVPA (min·day^{-1})	98.7 (7%)	77.4 (5%)	120.8 (9%)
FMS (SD)	66.4 (8.3)	66.8 (7.6)	66.1 (8.8)
Age (y)	9.7 (0.5)	9.5 (0.6)	9.8 (0.3)
BMI (kg·m^2)	17.9 (3.1)	17.7 (3.1)	18.3 (3.3)
Sex (M/F)	125/133	64/55	61/78

Note: SL: sleep; SB: sedentary behaviour; LPA: light physical activity; MVPA: moderate-to-vigorous physical activity; FMS: fundamental movement skill score; BMI: Body Mass Index.

Table 2. Pair-wise log-ratio variation matrix

	Sleep	Sedentary	LPA	MVPA
Sleep		0.136	0.162	0.380
Sedentary	0.136		0.537	0.592
LPA	0.162	0.537		0.603
MVPA	0.380	0.592	0.603	

LPA: light physical activity; MVPA: moderate-to-vigorous physical activity. A value approaching "0" indicates high proportionality between pairs of behaviours, whilst a value approaching "1" indicates the opposite.

Table 3. Linear regression of movement variables

	Sleep B [95% CI]	P value (r²)	Sedentary B [95% CI]	P value (r²)	LPA B [95% CI]	P value (r^2)	MVPA B [95% CI]	P value (r^2)
FMS (all)	-4.85 [-18.68, 8.98]	0.51 (0.04)	-10.98 [-23.56, 1.59]	0.08 (0.11)	4.49 [-8.81, 17.85]	0.51 (0.001)	9.47 [-8.4, 27.33]	0.29 (0.004)
FMS (UK only)	-4.88 [-13.15, 2.7)	0.43 (0.07)	-10.44 [-28.07, 7.19]	0.24 (0.09)	5.05 [-16.97, 27.07]	0.65 (0.04)	6.74 [-15.06, 28.56]	0.54 (0.05)
FMS (Iran only)	-4.82 [-12.75, 3.1)	0.55 (0.01)	-10.75 [-30.57, 9.06]	0.28 (0.09)	1.36 [-17.48, 20.22]	0.88 (0.01)	61.05 [11.07, 111.03]	**0.01** * (0.22)

Note. All adjusted for age, BMI and sex. B: Beta coefficient; CI: confidence interval; LPA: light physical activity; MVPA: moderate-to-vigorous physical activity; * significant at <0.05